FLUX ATTENUATION IN A STEEL SIDE SHIELD AT THE AGS

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Summary

The shielding properties of steel have been studied using an array of steel blocks near a target in the external beam of the AGS. Polyethylene foil detectors for $^{11}$C activation were used as beam monitors as well as to measure the flux distribution in the steel. Flux measurements were made on the face of the shield (10 in. from the beam axis) and at various locations in the array to a depth of 30 in. from the beam axis. In analyzing these results it is apparent that the usual models of exponential attenuation of flux with distance in the shield are unsuitable. A striking regularity is present; the ratio of radial distances from the target to isoflux lines is constant, independent of angle.

Introduction

High energy external beam lines require relatively thick radiation shielding near and downstream of the target regions. This shielding is most economical if it is "close-coupled", i.e., if the inner radius of the shield, assumed to be cylindrical, is as small as practical. Such a local shield should attenuate the prompt secondary flux and reduce activation of the inner surface of the outer biological shield. Preparatory to designing such a close-coupled shield, we measured the distribution of energetic (> 20 MeV) secondary particles in a steel side shield by means of $^{11}$C activation in polyethylene foils. The external proton beam (28 GeV, $10^{12}$ protons per AGS cycle, 24 cycles per minute) was incident on a tungsten target 0.4 in. x 0.4 in. x 1 in. long. The beam was well focused; the horizontal and vertical profiles show a Gaussian distribution with 97% of the beam within a circle 0.1 in. in diameter.

Procedure

For each run a monitor foil of polyethylene was placed atw hear the beam upstream of the target. Detector foils of poly 4 in. high x 1 in. wide x .008 in. thick were arrayed in the side shield with an average axial spacing of 7 in. and a transverse spacing of 2 to 4 in. The shield was composed of steel bricks 2 in. x 4 in. x 8 in., arranged to form a rectangular solid 20 in. high x 30 in. wide x 70 in. long with vertical slots approximately 1/8 in. wide running parallel to the beam axis for insertion of the detector foils.

The activities of both the monitor and detector foils were measured in the same well counter which eliminated normalization errors.

The data presented here are corrected for background; the normalized flux in the shield with target removed was subtracted from the normalized target in flux for each run. This correction was only significant near the upstream end of the shield, the source then was apparently the vacuum window and upstream apertures. Reproducibility in four runs was good, and we estimate the overall error to be about 10%. Statistical uncertainty in the data is less than 1%.

Results

A schematic of the experimental layout, and the isoflux contours are shown in Fig. 1. The axial distribution of flux for various transverse distances in the side shield shown in Fig. 2, the transverse distribution in Fig. 3.

Discussion

It is apparent from the figures that a simple geometric and exponential attenuation of the flux in the shield is not accurate. However, if at a given angle the ratio of radial distances from the target to two isoflux lines is determined it is found to be the same for all angles, Indeed the ratio of ratio is determined only by the ratio of fluxes on the isoflux lines. Thus if any isoflux line is known in the shield all other isoflux lines in the steel may be found from the relation

$$\frac{\delta \psi}{\delta \psi'} = e^{-(\gamma - 1)}$$

where primed quantities refer to the known isoflux contour and

$$\gamma = (\ln 10)/(\Sigma - 1)$$

where $\gamma$ is the radius ratio for a flux ratio of 10.

This relation was applied to the flux distribution in the sand side shield measured at the AGS in 1966* and found to be compatible with those data also. This was not a close-coupled shield since the separation of the shield from the beam axis was 12 ft. We find that for the steel shield $\Sigma = 1.57$, for the sand shield $\Sigma = 1.17$.

The flux distribution reported here differs significantly from a corresponding study performed at the CERN PS* in 1964 with a very similar steel side shield. They show isoflux contours from carbon-11 detectors for beams of 10 and 19.2 GeV/c protons on a beryllium target.

References

Figure 1 - Isoflux contours in steel side shield. Contour units are energetic (> 20 MeV) particles/cm²/proton incident on the target.

Figure 2 - Secondary flux versus axial depth in the shield.

Figure 3 - Flux versus transverse depth in shield.